

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE May 1999		3. REPORT TYPE AND DATES COVERED Final, 1 April '97 - 30 Sept. '98
4. TITLE AND SUBTITLE  Hand Tool Manipulation and Self-Presence in VR			5. FUNDING NUMBERS  G N00014-97-10396	
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Pennsylvania Computer & Information Science Dept. 200 S. 33rd St. Phila., PA 19104-6389			8. PERFORMING ORGANIZATION REPORT NUMBER  Not applicable	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research, Code 1141SB 800 N. Quincy Street Arlington, VA 22217			10. SPONSORING / MONITORING AGENCY REPORT NUMBER  Not applicable	
11. SUPPLEMENTARY NOTES  None				
12a. DISTRIBUTION / AVAILABILITY STATEMENT  Distribution Unlimited			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  The objective was to purchase Virtual Reality and associated computing equipment to enable the investigation of full body avatar control and self-presence using both fine motion hand manipulation plus force feedback as well as whole body posture and motion sensors.				
14. SUBJECT TERMS Virtual Reality, motion sensing, self-presence, force feedback.			15. NUMBER OF PAGES 4	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

## FINAL REPORT

GRANT #: N00014-97-10396

PRINCIPAL INVESTIGATOR: Dr. Norman I. Badler

INSTITUTION: University of Pennsylvania

GRANT TITLE: Hand Tool Manipulation and Self-Presence in VR

AWARD PERIOD: 1 April 1997 - 30 September 1998

OBJECTIVE: To purchase Virtual Reality and associated computing equipment to enable the investigation of full body avatar control and self-presence using both fine motion hand manipulation plus force feedback as well as whole body posture and motion sensors.

APPROACH: Creating whole body avatars requires software to model and move the virtual human body representation of self. We already had in house Jack software that served this purpose. But we had no modern VR instrumentation that would be able to effectively sense a live participant's hand and body attitude, and provide this information to the Jack software in a usable format. New VR tools and computing power were added in our laboratory through this grant to enable real-time human motion capture and hand force feedback.

ACCOMPLISHMENTS: The purchased equipment has been an integral part of the Center for Human Modeling and Simulation's laboratory facilities. It has been used to study human gestures, the "feel" of small hand tools and instruments, and motion capture mapping across different sized-individuals.

- In studying human gestures, the equipment was used to capture the gestural and postural motions of dancers, movement notators, music conductors, and American Sign Language signers. Position, velocity, acceleration, and jerk (3<sup>rd</sup> derivative) curves were obtained from live motion capture using the VR sensors and the computers. From these observations, a kinematic theory and implementation of gestural Effort was proposed in Diane Chi's PhD Dissertation. This system uses just four parameters -- derived from Laban's Efforts -- to

qualitatively change the performance of given arm gestures of an animated character.

- To understand the "feel" of small handtools, a demonstration system was constructed by Drew Kessler and undergraduate Mark Palatucci. They graphically modeled a small pistol and its trigger, then developed the force-feedback structure that drove the CyberGrasp glove. The user wearing the glove could feel the pistol and the grip, and could feel the movement and resistance of the trigger. By aiming at a simulated target, the user could experience a virtual shooting range.
- Motion capture for whole body avatars is complicated by the typical requirement that the graphical model have the exact same articulation and body segment (joint-to-joint dimensions) as the user. The calibration of the motion sensing device to the individual user is tricky at best and always awkward. Errors in matching the model to the user result in captured motions that relate improperly to objects in the environment or features on the user's self: for example, accurate reach to grasp and move a glass from table to mouth is difficult or impossible. The problem is that the joint angles of the user are not matching the joint angles of the model. Likewise, features (such as the mouth) may be at different locations in space. Our approach is to use semantic features on the model and acceleration changes (zero-crossings) to determine spatial adjacencies of limb and object that appear important. These adjacencies are used to drive an inverse kinematics algorithm that automatically adjusts for the differences in segment length. Additionally, the motion style (velocity profile) along the movement is scaled and preserved. As a demonstration of the approach, an adult user controlled the motions of a child-sized model drinking from a glass. The eye gaze of the child model was also corrected for the spatial mismatch in sizes and feature locations. This work by Rama Bindiganvale, was reported at the Motion Capture Workshop in Geneva, Switzerland, in November 1998.

CONCLUSIONS: Our work with the VR sensors and force feedback has led directly to one PhD (Chi) and one published conference paper (Bindiganavale and Badler). The preliminary work by Bindiganavale will be incorporated into her PhD Dissertation as well. The VR target range was documented in a videotape by Palatucci and Kessler. We

were able to do this research as a direct consequence of the new VR and computing equipment purchased on this DURIP grant.

SIGNIFICANCE: We have a much better understanding of how live user input can be used to drive a 3D articulated human model of a different size. We also have a parameterized model of human gesture based on Laban Efforts. This model is the first implementation and computational evaluation of the Laban Effort system, a widely used notational system for qualitative human movements.

PATENT INFORMATION: There are no patents filed based on this work, though the feasibility of a patent on Chi's gesture work was investigated.

AWARD INFORMATION: Diane Chi received her PhD in Computer and Information Science in 1999.

#### PUBLICATIONS AND ABSTRACTS:

``Real time virtual humans'' International Conference on Digital Media Futures, Bradford, UK, April 1999. (N. Badler, R. Bindiganavale, J. Bourne, J. Allbeck, J. Shi and M. Palmer).

``Virtual human animation based on movement observation and cognitive behavior models,'' Computer Animation Conf., Geneva, Switzerland, May 1999. (N. Badler, D. Chi, S. Chopra).

``Where to look? Automating visual attending behaviors of virtual human characters,'' Autonomous Agents Conf., Seattle, WA, May 1999. (S. Chopra and N. Badler).

``Smart avatars in JackMOO,'' Proc. Virtual Reality '99, Houston, TX, IEEE Computer Society, March 1999. (J. Shi, T. J. Smith, J. Granieri, and N. Badler).

``A parameterized action representation for virtual human agents,'' Workshop on Embodied Conversational Characters, North Tahoe, CA, October 1998. (N. Badler, M. Palmer, R. Bindiganavale, and W. Schuler).

``Gesticulation Behaviors for Virtual Humans'' Proc. Pacific Graphics, Singapore, 1998. (L. Zhao and N. Badler).

``Motion abstraction and mapping with spatial constraints,`` Workshop on Motion Capture Technology, Geneva, Switzerland, November 1998. (R. Bindiganavale and N. Badler).

``Avatars a la Snow Crash,`` Proc. Computer Animation, June 1998. (J. Allbeck, N. Badler).